Missouri River at Wolf Point, Mont., and the Mississippi River at Fort Ripley, Minn., on the 6th.

The highest and lowest water, mean stage, and monthly range at 216 river stations are given in Table VI. Hydrographs for typical points on seven principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.—*H. C. Frankenfield, Professor of Meteorology.*

SPECIAL ARTICLES, NOTES, AND EXTRACTS.

THE CLOUDS OF VENUS AND THEIR SIGNIFICANCE.[1]

By ARTHUR W. CLAYDEN, M. A.

If it be assumed that the visible surface of Venus is the outer face of a heavily cloud-laden atmosphere, comparable in mass and composition with our own, it seems that certain deductions may be based on its observed features which have not hitherto been pointed out, though they convey valuable hints as to the planet's physical condition, the position of its axis, and the period of rotation.

There is no need to recapitulate here the many reasons for believing that the surface visible to most telescopes is actually cloud, and the sequel will show that such a view is not incompatible with the detection of sharp markings such as have been described by specially favored observers. My own observations have been made with the 6.8 inch refractor by Tully, described in Vol. II of the Society's Memoirs. Its long focus (144 inches) gives excellent definition of Jupiter and Saturn, when the seeing is good, with powers up to 450; but it has never shown me anything on Venus which does not seem easily explicable on the assumption that the planet is shrouded in clouds, and that its atmosphere bears something like the same relation to its mass as our own atmosphere does to the earth's.

Taking this for granted, let us consider how those clouds should be distributed according to different views as to the period of rotation and the position of the polar axis.

LONG ROTATION PERIOD.

First let us assume that the axis makes a large angle with the plane of the orbit, and that the period of rotation is coincident with the revolution. That is to say, that the planet always turns the same face to the sun—one side always exposed to the solar glare, and the other feeling the full effect of continuous radiation into space.

In this case, even allowing for considerable libration, it is more than difficult to imagine how the clouds are maintained on the sunlit face at all. The whole of the water should long ago have been distilled on to the dark side, and there locked up in the form of ice. It seems impossible that there should be an atmospheric circulation capable of keeping up a high enough temperature on the cold hemisphere to allow of the return to the hot one of a sufficiently large amount of water to produce the clouds. We can not call to our aid a circulation of water in the liquid state, for rivers are dependent upon rainfall or thawing ice, and the very seas should have been distilled. A slow glacial creep seems the only possibility, and that could hardly suffice to do more than produce a ring of cloud along the terminator, leaving the greater part of the hot hemisphere to stand out naked to the sunshine and to our view. Moreover, the phenomena seen along the terminator show no symptoms of great and rapid movements of the atmosphere, such as should certainly be the case if the continuity of a reasonable balance of temperature, and therefore of humidity, were dependent even indirectly upon them.

It may be contended with some reason that the great pall of clouds will moderate the temperature of the sunlit face, but this hemisphere must, on the whole, be one of rising convection currents, while the dark side must conversely be one of descending currents. Descending movements mean clear skies, and therefore unchecked radiation; so, whatever the initial temperature of the dark face may have been when last shut off from the sun's heat, it can not have been protected by a blanket of cloud, and must be intensely cold.

The assumption of a high internal temperature is no more satisfactory, for the same causes which should have frozen the water should have previously chilled the solid rocks, and have thereby placed a thick protecting shield between the hot interior and the frozen surface. If we allow for the difference in the internal pressures, the densities of Venus and the earth are so near as to imply not only identity of composition but a close similarity of condition.

It seems that the only way in which the persistence of the cloudy envelope could be explained, would be to assume a thermal conductivity for the mass of the solid planet far higher than that of the materials of the earth.

In the absence of any such extravagant and improbable supposition, it thus appears that the continued existence of the cloudy shell affords an almost conclusive negative to the possibility of an exact identity between rotation and revolution.

SHORT ROTATION PERIOD.

Next, suppose the axis to make a large angle with the plane of the orbit, and that the rotation period is not very different from the length of a terrestrial day.

In this case it is at once obvious that the distribution of temperature on the planet should be strictly similar to that on the earth. The actual values might be everywhere higher, but the gradients should be in precisely the same directions. Of course the local variations due to the distribution of land and water would differ, but the broad differences due to latitude and the time of day should present an exact parallel.

Moreover, the laws of motion which govern the movements of our atmosphere, and combine with the results of the temperature gradients to determine the general arrangement of atmospheric pressure and the great wind systems, must inevitably produce effects on the somewhat smaller planet, just like those which dominate the meteorology of the earth.

The region of ascending or cloud-producing currents must be similarly distributed, and the descending or cloud-destroying currents must occupy the same relative places.

The result should be a belt of uprising currents surrounding the planet's equator at its equinoxes, and moving more or less toward each pole in turn with the progress of the seasons. North and south of this, at about the latitude of 20° or 30°, there should be a belt of higher pressure, and therefore of descending motion, while farther away from the equator toward each pole the chief drift of the atmosphere should be tangential and moving with the rotation.

There should therefore be a shining white belt over the equatorial low pressure, flanked on either side by a band where clouds should be small and scanty, and therefore much less brilliant. Then again, brighter regions should extend to each pole.

Moreover, such a circulation should give rise to storms analogous to our own, moving over the planet in the same way, and their courses should often be clearly visible.

The earth must show all these features so plainly that they would be the first thing noticed. Except in the region of our tropical belts of high pressure an astronomer on Venus would

[1] Reprinted, by permission, from the Monthly Notices of the Royal Astronomical Society, January, 1909, 69:195–204, and accompanied by illustrations [Chart IX] from sketches by the author.

rarely be able to make out much of terrestrial geography. The belt of clouds marking the position of the equatorial rainy season must stand out as a shining white band, in strong contrast with the darker belts on either side. All details of the world's temperate zones must be masked in the most annoying way, for it must be very rare that a district so large as the British Isles is entirely free from cloud, even if we exclude cirrus from consideration.

FIG. 1.—The earth (a belted planet) as it would appear from Venus.

In fig. 1 we have a view of the earth as it would probably appear to an astronomer on Venus, but the parts of the oceans visible would be tinted with a pale shade of indigo, while the land surfaces would be tinged with shades of ruddy brown or dark green, thereby adding to the contrasts.

There is no question that the earth is a belted planet; and if Venus had a rotation period comparable with our day, and if the atmosphere is of similar or greater density than ours (which is essential for the formation of the shell of convection clouds), she also would take a place in the same group. It is true that Mars does not, but its small mass and the low value of gravity are sufficient to account for the absence of the lower clouds, and these are those which form the belts.

There seems, therefore, no reasonable doubt that if the polar axis of Venus forms a large angle with the plane of her orbit, her rotation period can not be anything like so short as the length of our own day. In Chart IX, fig. 2, we see the sort of shading which the planet ought to show under such circumstances..

Suppose, next, that the axis is very little inclined to the plane of the orbit, as has been sometimes suggested. Apart from all mechanical difficulties in the way of such a supposition, the behavior of the cloud stratum affords a sufficient test. Each pole will in turn be heated and cooled, so the general distribution of temperature will be different. But at each equinox the temperature gradients should be in directions similar to those presented in the last case. From the equator toward the pole last presented to the sun the gradient would be small, but it would be very steep toward the other. The planet should therefore show a bright equatorial band shading away toward the warmer pole, and flanked on the side toward the colder pole by a clearly marked dark belt. Chart IX, fig. 3, shows the planet as it should appear under these circumstances, supposing the axis to be inclined about 35° to the ecliptic and the warmer pole to be inclined toward the observer. That it does not show a trace of any such feature, or any other symptom similar to the former case, is a sufficient proof that the supposition is not a fact.

It thus appears that the short rotation period can not be true in any position of the axis, and that the planet's day and year can not be identical. In one case we ought to see things which we do not, and in the other we ought not to see what we do.

THE MOST PROBABLE PERIOD.

The objections to a short period are equally valid for any period shorter than our own day, and for any period longer than the earth's up to one as long probably as our week or more, but the difficulty with the long period is only applicable to exact identity between the planet's day and year. If the actual length of its day falls only a little short of the time of revolution, all parts of its surface will in turn experience the extremes of heat and cold. Probably any period between 20 of our days on the one hand and, say, 180 or 200 days on the other, would give conditions in which no cloud bands or high-pressure tropical belts would be produced parallel to the equator and no permanent locking up of the water could occur.

The estimates made, with the exception of Bianchini's 24 days 8 hours, all indicate a period similar to our own day, or one nearing the length of the planet's year. If the markings upon which these measurements were based were actual features of the planet, or effects produced upon the clouds by underlying features, and not mere atmospheric phenomena owing their position to the time of day or drifting wind, it seems most probable that Venus rotates upon her axis in a time which approaches the length of her year, but differs from it sufficiently to enable water to be carried across the sunlit face without complete evaporation.

Upon this supposition, it seems easy to explain several of the best known and most easily observed phenomena presented by the planet in its different phases, including that error of phase which has not hitherto received any satisfactory interpretation.

Suppose, then, that the axis is highly inclined to the plane of the orbit, and that the rotation period is long—so long that the law of equal areas, Ferrel's law of the deflection of currents moving over a rotating body, and the law of centrifugal force do not exercise any dominating effect on the atmospheric circulation.

Under these circumstances, temperature on the sunlit face will be lowest at the poles and along the sunrise terminator. It will increase to a maximum at a point on the equator west of the noon meridian, and will decrease toward sunset and across the dark side until the day is again breaking. The hottest region will not be a belt, but an oval area with a steep gradient of falling temperature toward the poles and sunrise terminator and a gentler gradient toward the sunset.

There should be, therefore, a region of expansion over the hottest area, from which the upper layers of the air should flow radially outwards in all directions, following the gradients of decreasing temperature, exactly as our atmosphere overflows from the equatorial low-pressure belt to the Tropics.

Just as the terrestrial overflow results in the overloading of the lower air along the two anticyclonic belts of Cancer and Capricorn, so in the case of Venus the radial overflow must create a ring of higher pressure about 30° or 40° away from the maximum temperature, and therefore low pressure, on every side.

In the case of the earth the bands are irregular, and frequently incomplete, owing to the distribution of land and water. This would probably be the case with Venus. The exact position and intensity of the high-pressure ring should vary slightly from time to time as the diverse hidden features of the planet pass beneath it on their journey across the disk. Nevertheless, it should always be there and, from the difference in temperature gradients toward sunrise and sunset, it should be much more marked on the morning side than on the other. In our own atmosphere[2] we have in the constant small rise of the barometer between 9 and 10 a. m. a clear indication of a similar tendency to the formation of a ring of high pressure around the areas of greatest heat.

Beyond the high-pressure ring there should be a fall of pressure toward the terminator on every side into the darkness, but the pressure should rapidly increase again to a great maximum covering a large part of the dark hemisphere.

Low-pressure regions mean ascending currents and the abundant formation of convection clouds of the cumulus, cumulus-nimbus, and cyclonic types. High-pressure regions, on the other hand, mean descending movements and scanty formation of convection clouds. Even when the sunshine does produce local ascending currents in such a region, they are stunted by having to rise against the general descent, and the cumulus clouds produced are small and scattered, leaving wide interspaces through which descent goes on.

The whole area on the face of Venus within the high-pressure ring should be covered with ascending cloud columns; and if moisture is abundant enough, a dense mass of convection clouds like those which accompany our equatorial rains, should reach high up above the body of the planet.

The high-pressure ring should be checkered with smaller detached cumulus, like those of our trade wind zones, less brilliant because deeper down, and because the interspaces should let us see still deeper, even perhaps to the shaded surface of the planet itself. Here, if anywhere, there would be the best chance for us to glimpse something of the planetary geography, but any markings would look as if seen through a luminous mist caused by the detached clouds.

Beyond this ring of lesser brightness the convection clouds should again rise above the surface, but should rapidly lessen in altitude as the terminator is approached.

At eastern elongation the terminator is probably sunrise and the clouds are growing. As they are carried slowly forward into the day they should rise higher and higher. On reaching the high-pressure ring they would be degraded, broken, and perhaps to a great extent destroyed. But beyond this they would be reinforced by still stronger convection until the hottest region had been crossed. From this point degradation should again set in, and toward sunset there would be a rapid fall in their level, so that their upper surfaces should slope rapidly downward into the night.

Now, convection currents rising from the ground do not lift their burden of cloud particles indefinitely. The very formation of the cloud, by loading the air with particles of liquid water or solid ice, tends to check the ascent, and the thermal effects of expansion, with the fall of rain and hail, combine to put a limit to their possible stature. On the earth they do not reach beyond 5 or 6 miles from the ground.

But the sun's rays falling on the upper surface of a stratum of such clouds evaporates water from them, and this is carried upward by the general ascent of the air over a low-pressure area until it reaches such altitudes as 9 or 10 miles, or more. Here it condenses into fine particles of ice, and forms the great variety of translucent clouds classed as cirrus and cirro-nebula[3].

[2] See O. L. Fassig in Proc. 3d Convention, Weather Bureau officials, at Peoria, Ill., 1904. Washington, 1904. 8 vo. p. 117, fig. 4 and Chart I.—*C. A., jr.*

[3] Mr. Clayden designates as "cirro-nebula" the thin veil-like clouds which produce halos. It is much thinner and usually higher than cirro-stratus. See his "Cloud Studies," London, 1905. 8vo., pp. 24–28 and plates 3 and 4.—*C. A., jr.*

When we bear in mind the greater intensity of solar radiation on Venus, we see that both convection from the ground and this upper circulation should take place on a grander scale than anything we experience. Its atmosphere should probably be richer in water vapor, both classes of cloud should be more abundant, and, owing to the smaller value of gravity, the altitudes reached should be greater.

Since atmospheric pressure should, on the whole, be considerably greater on the dark side than on the one turned toward the sun, the upper currents should flow from the hot side over the high-pressure ring and toward the terminator, while colder under currents should flow in the opposite direction.

The cirrus clouds floating in the upper currents should thus pass constantly across the terminator on all sides, and persist some distance beyond. They are always thin, and generally scattered. If the base of the atmosphere on Venus is at a higher temperature than is the case with the earth, a supposition which is almost certainly true of the greater part of the sunlit face, cirrus clouds should not form until an altitude is reached at which the pressure is lower than that required for their formation here. They should, therefore, be loftier and even thinner than ours, and ours do not hide the sun. They are shining white by transmitted light, and shine most brilliantly when viewed edgewise.

The whole sunlit face of Venus should thus be covered with a delicate, filmy network of cirrus, similar to that which enfolds the earth, varying in density and transparent as a whole when viewed at a considerable angle, but becoming whiter and more opaque as the obliquity of the point of view increases.

Observational evidence.

Now there are certain distinct phenomena which have been repeatedly described, and which may be seen under suitable circumstances with quite moderate telescopes, which seem to me to admit of simple explanation if the foregoing hypotheses are correct.

1. The brightening of the limb relative to the rest of the disk.

This is a distinctive feature of all planetary bodies which may be reasonably supposed to have at most a thin, pure atmosphere above the reflecting surface.

In the case of Venus it may be explained as due in the first instance to the fragmentary veil of cirrus, which stands out more and more brilliant as it is seen more obliquely. Being higher in the atmosphere its particles would be brighter, area for area, than those of the lower clouds, whose summits would be seen through a greater thickness of air, and would also to some extent be shaded by the cirrus itself.

If the cirrus sphere could exist in space alone, we should see only a slender ring of light, very lustrous on its external margin, but rapidly fading away to a dark interior.

2. The prolongation of the cusps.

If the cirrus veil is, as would almost certainly be the case, some miles above the convection clouds, it would catch the light several degrees beyond the true terminator. Since the air at such an altitude is practically free from dust, and since all the lower layers of the atmosphere are densely laden with opaque cloud, we can not expect that even the tips of the horns should be illuminated by sunset coloring. This can only be produced when the rays have passed through the lower air. The light should therefore be sensibly white, or at most a pale yellow. The thinning of the cusp to a fine, sharp line would be due to the fact that as the intensity of illumination diminishes with distance from the true terminator, the film of cirrus will need to be seen more and more obliquely for a given brightness. It should, therefore, thin out exactly as it does.

3. Detached points beyond the tips of the horns, and occasional absence of the horns.

Cirrus clouds are not continuous. They do not form a continuous layer around the earth, nor is there any reason to suppose they should do so on Venus. Hence, if one of the clear spaces should happen to be in the right position, we should see through the gap, and the horn would be absent or broken.

Moreover it may be assumed that the planet is diversified by mountains and valleys like our own, and that these are probably of similar stature and depth.

When the great air-currents flow over such features, up and down movements are produced, which react upon any cloud zones above, destroying the clouds by a descent in one place, creating them or throwing them up to an abnormal height by an ascent elsewhere.

We can thus explain irregular or even periodic appearances of projections of the bright surface, or the occurrence of dark spaces in it, by attributing them to the passage of the cloud-laden air over an uneven surface beneath. Projecting points of light may well be thrown up to very great altitudes without needing to suppose mountains so vast that they would flatten out under their own weight.

4. The acceleration of phase in eastern elongation is commonly observed to vary from four to eight days—dichotomy, or any special phase, being so much earlier than the theoretical time.

This can only mean that the surface along the sunrise terminator is not at right angles to the planet's radius, but that it slopes upward toward the sun, and that the slope is steepest in the equatorial regions, and diminishes toward the poles.

But this is exactly how the upper surface of a shell of rising convection clouds should rise, and the fact alone is an almost conclusive proof that the cloud theory is right.

The phenomenon is not limited to dichotomy, but can be noticed at any time not far removed from greatest elongation.

The variation of the acceleration would imply a variation in the slope such as would be a natural consequence of changes in the underlying surface due to the slow rotation relative to the sun which has been postulated as essential to the permanent maintenance of the clouds.

5. The retardation of phase in western elongation is rather more pronounced. It can be explained as due to an even greater slope of the mean surface of the clouds, due to the collapse of the rising currents and breaking down of the clouds toward sunset. On the earth the fall of the cloud levels in the evening is distinctly more rapid than their morning rise. The fact may be regarded as a proof confirmatory of the last.

6. The shading off of the terminator and,

7. The variable contour of the terminator would both be the natural result of variations in the height to which the clouds had reached in consequence of differences in the nature, and therefore temperature or moisture of the surface beneath.

8. The smaller luminosity of the neighborhood of the terminator.

Apart from the glittering margin, which has been attributed to the cirrus veil, and apart from any definite darkening of a particular region, this is perhaps the most obvious feature of the planet.

At the limb we see only the shining cirrus. Elsewhere we look through it onto the summits of the convection clouds. If, as appears to be almost certain, the individual clouds have on the whole a roughly pyramidal or pillared contour like our cumulus and alto-cumulus castellatus, the body of the planet would be brightest near the limb, where only the tips of the clouds would be seen. On passing from the limb toward the center of the disk, we should see farther and farther into the shadows between them, and the proportion of shade should increase as the sun's rays become more oblique.

9. The presence of a faint band of shade, approximately parallel to, but at some distance from, the terminator.

This can nearly always be seen. It is not sharply contoured, but broad and ill-defined. Still a graduated shade, such as a neutral tint wedge, will generally bring it out. It is best seen in eastern elongation when the planet is near dichotomy, or approaching its maximum brilliancy. It varies from time to time in breadth and depth of shade, but always occupies the same position relative to the terminator. It can not apparently be followed into the shining ring near the limb. It has been described by M. Antoniadi in the Monthly Notices of the Royal Astronomical Society for March, 1898, and its appearance is shown in Chart IX, figs. 4 and 5, which are, of course, on different scales.

Surely this is a high-pressure ring, darker than the rest because we see deeper into it, and the spaces between the clouds are larger. It is much less pronounced in western elongation, as we should expect should be the case from the difference between the temperature gradients toward sunrise and sunset.

10. The mottling or granulation of the surface, the appearance of dark or bright spots moving over the terminator, and the occurrence of bright points beyond it, are all phenomena which should be visible, and receive obvious explanations.

11. The ring of light seen at inferior conjunction, and usually attributed to atmospheric refraction, would more probably be nothing but the edge of the illuminated shell of cirrus. This stratum would, everywhere around the terminator, be several miles above the clouds, and perhaps 10 or 20 miles above the actual surface of the planet. Mere refraction ought to give a ring of colored light, yellow, or even red. But if the lower air is, as has been supposed, blocked by heavy convection clouds, all colored rays would be stopped, while the high cirrus would shine with the silvery light we see.

At such altitudes atmospheric refraction would be almost negligible, and a calculation based upon the position in which the circle is complete would give the height at which these delicate structures float, if only we knew how much to allow for that rise of the lower clouds near the terminator to which we have attributed the error of phase.

The phenomenon, then, may be regarded as only another aspect of the same fact which also explains the prolongation of the cusps.

Finally, if we suppose that the convection clouds do not form a continuous sheet, but are distributed broadcast with clear intervals for the descending partial currents which should accompany them, it becomes easy to believe that under suitable circumstances and with sufficiently powerful optical means, it may sometimes be possible to penetrate the veil, and see at least some of the most salient features of the planet's actual surface. On the other hand, the underlying surface must react upon the clouds above, and it may well be that those sharply defined markings which have been recorded are nothing more than a result marked out upon the veil by the features hidden beneath.

THE MOON BLAMELESS.

We print in full the following letter to the New York Herald of May 31, 1909, from the prominent and popular French astronomer, Cammille Flammarion, as an influential contribution to the constant warfare between superstition and truth. While written particularly for the wine-growing districts of France, every word applies with equal force to the corresponding districts of this country. Even the general farmer would do well to consider the application of these simple and rational explanations to many of his problems and catastrophes.—*C. A. jr.*

OBSERVATORY OF JUVISY,
PARIS, FRANCE, *May 11, 1909.*

TO THE EDITOR OF THE HERALD:

The April moon again is astir with its peculiar influences. Radiant, warm afternoons, alluring as a tropical day almost, have been succeeded by nights quite as radiant, but as cold as in winter. At the end of April and the beginning of May we have been blessed with spring during the